Strength and Deformation Properties of Soil-Cement

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Sponsor: Deep Foundations Institute

Start/Completion Dates: January 2016 / May 2017

Project Background
The deep mixing method has experienced substantial increase use during the last decade. Nevertheless, the engineering design community continues to have questions about the applicability of deep mixing, particularly concerning strength and modulus properties of soil-cement under the wide variety of loading conditions encountered in practice, as well as appropriate laboratory test procedures for determining design values and for quality assurance programs during construction. The overall goal of this project is to provide reliable information about relationships between strength and deformation properties of soil-cement mixtures, as well as recommendations regarding appropriate laboratory procedures to determine these properties during design and verify them during construction.

Project Objectives
The principal objectives of this research are to investigate:

1. Procedures for treatment of specimens ends prior to testing.
2. Relationships among compressive strength, shear strength, tensile strength, and modulus values, including the influences of confining pressure, as well as the difference between total and effective stress characterization of strength.
3. The behavior of soil-cement at large strains.

Laboratory Testing
The laboratory testing program includes development of a laboratory mixing procedure, unconfined compression tests, splitting tensile strength, unconsolidated-undrained triaxial tests, and isotropically consolidated-undrained triaxial tests. Local strain measurements were obtained on many of the unconfined compression tests.

Important Findings
The research has produced several significant findings. A few of these are described below:

1. End treatment method does not have a large impact on the unconfined compressive strength. However, the methods of grinding, and sawing and hand trimming are preferred. The preparation time for sulfur capping and gypsum capping is long, and without the proper measures, it can result in drying of the specimen. Neoprene pads produce a failure mechanism different from the rest of the methods due to the pads expanding laterally under load. This failure mechanism causes uncertainty in the test results.
2. The modulus of elasticity at 50% of the unconfined compressive strength is higher for local strain measurements than for end platen measurements. The end platen measurements include machine compliance and deformations that are not related to the specimen, and thus result in larger values of strain. The local strain measurements are recorded directly from the specimen, and they result in more accurate deformation measurements. For the
tested mixtures, the modulus of elasticity from local strain measurements is about five times larger than that from the end platens. This is shown in Figure 1.

![Figure 1](image1.png)

**Figure 1:** Relationship between modulus of elasticity and unconfined compressive strength.

3. The three-coefficient best-fit approach was further investigated by changing the water-to-cement ratio of the slurry as well as changing the binder factor to obtain a wide variation of total-water-to-cement ratio of the mixture. The three-coefficient best-fit shows very good agreement for the lower strengths, and as the strength of the mixture increases, the fit exhibits more scatter, as shown in Figure 2.

![Figure 2](image2.png)

**Figure 2:** Three-coefficient best-fit to represent UCS as a function of total-water-to-cement ratio and curing time.